Comparison of Off-Leakage Current between LTPS and HTPS TFTs using Activation Energy and Device Simulation

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INTRODUCTION

Poly-Si thin-film transistors (TFTs) have been widely utilized for flat-panel displays (FPDs), such as liquid-crystal displays (LCDs), organic light-emitting diode displays (OLEDs), and electronic papers (EPs). Although the reduction of the off-leakage currents is also important, the mechanism of the off-leakage currents has not yet sufficiently discussed. In this presentation, we will compare transistor characteristics between low-temperature processed poly-Si (LTPS) TFTs [1] and high-temperature processed poly-Si (HTPS) TFTs [2], which are two typical kinds of TFTs, using activation energies and device simulation and clarify the mechanism of the off-leakage currents.

TRANSISTOR CHARACTERISTIC

LTPS TFTs are fabricated using the usual fabrication processes including excimer laser crystallization (ELC) [1]. HTPS TFTs are fabricated using the usual fabrication processes including solid-phase crystallization (SPC) [2]. Both the TFTs have the lightly-doped drain (LDD) structure. Although the device dimensions are slightly different between them, we think that we can compare them in the following sections.

The temperature dependences of the transistor characteristics are shown in Fig. 1. The field effect mobility (μ_{FE}) of the LTPS and HTPS TFTs are 67 and 38 $cm^2V^{-1}s^{-1}$, respectively. It is found that the temperature dependences of the off-leakage currents are larger than those of the on currents for both the TFTs.

The activation energies (E_a) of the transistor characteristics are shown in Fig. 2. In the off states, E_a for V_{ds}=0.1V is higher than that for V_{ds}=5V for both the LTPS and HTPS TFTs. E_a for V_{ds}=5V decreases as $|V_{gs}|$ increases only for the LTPS TFT.

MECHANISM ANALYSIS

The simulation results of the hole density and electric field around the junctions between the channel, LDD, and drain regions are shown in Fig. 3. It is found that a hole channel is lightly formed at the front-insulator interface in the LDD region, which originates from the carrier diffusion from the channel region. A pseudo p/n junction and a depletion layer appear at the junction between the LDD and drain regions, which make the electric field strong. The off-leakage current will be caused by the carrier generation there.

We will assume that the carrier generation is caused by the phonon-assisted tunneling with Poole-Frenkel effect (PAT) [3]. The simulation results of the energy band around the junction between the LDD and drain regions and PAT mechanism are shown in Fig. 4. A, B, and C in Fig. 2 roughly correspond to A, B, and C in Fig. 4. First, in the A state, the electric field exists due to the built-in potential. Because both |Vgs| and Vds are small, the electric field is gentle. An electron (e^-) is activated from a trap state in the bandgap to a certain energy level by the thermal activation and transported to the conduction band (E_c) by the tunneling. A hole (h^+) is activated from the trap state to a certain energy level and likewise transported to the valence band (E_v), and vice versa. Roughly speaking, the generation rate is approximated to be proportional to $\exp(-E_a/kT)$. Next, in the B state, because V_{ds} increases, the electric field becomes steeper, and E_a decreases. Finally, in the C state, because $|V_{gs}|$ increase, the electric field becomes further steep, and E_a further decreases for the LTPS TFT. For the HTPS TFT, E_a does not decrease so much. We think that this is due to the short tunneling length, which should be discussed in the future.

ACKNOWLEDGEMENT

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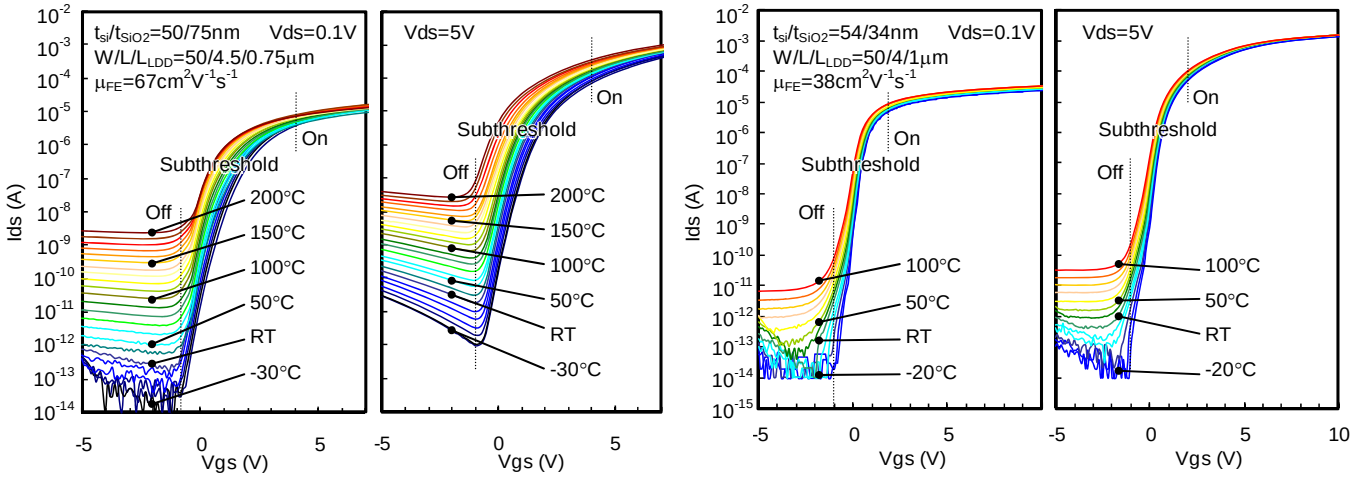
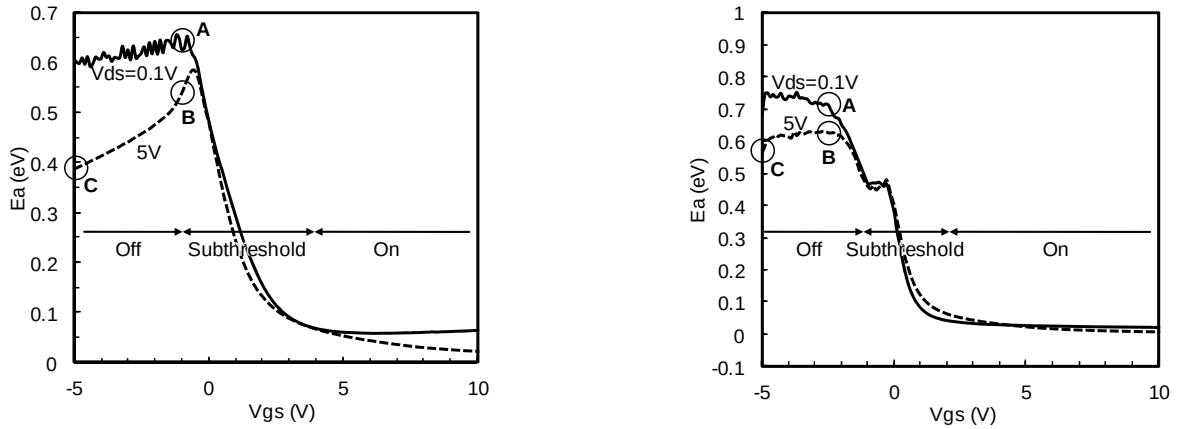


(a) LTPS TFT (b) HTPS TFT

Fig. 1. Temperature Dependences of the Transistor Characteristics



(a) LTPS TFT (b) HTPS TFT

Fig. 2. Activation Energies of the Transistor Characteristics

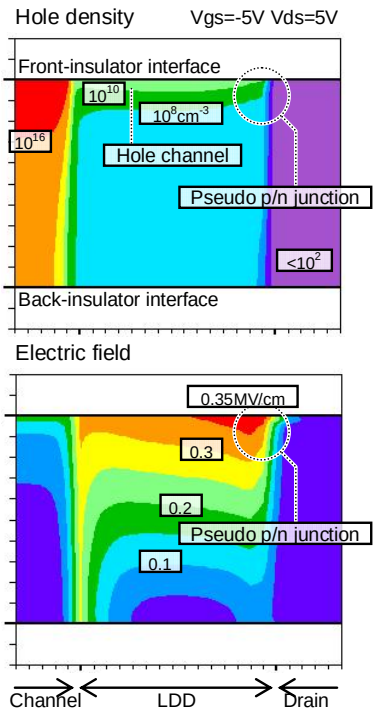


Fig. 3. Simulation Results of the Hole Density and Electric Field around the Junctions between the Channel, LDD, and Drain Regions

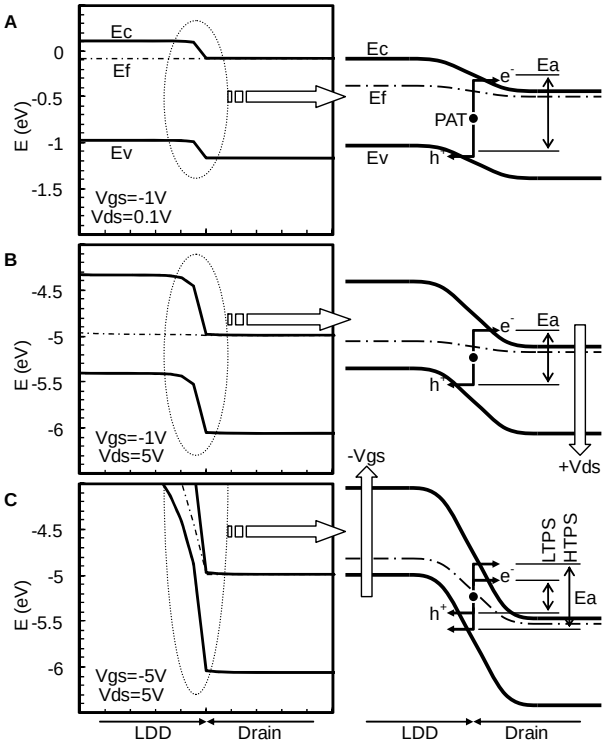


Fig. 4. Simulation Results of the Energy Band around the Junction between the LDD and Drain Regions and PAT Mechanism